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Feature Importance Analysis of Organizational Citizenship Behaviors in Driving Product Innovation Performance via XGBoost Models

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A B S T R A C T

Objective: The objective of this study was to identify and quantify the relative importance of organizational citizenship behavior dimensions in predicting product innovation performance using an explainable machine learning framework.

Methods and Materials: This study employed a quantitative cross-sectional design with data collected from 412 employees working in medium and large organizations. Organizational citizenship behaviors were measured across five dimensions including conscientiousness, civic virtue, courtesy, altruism, and sportsmanship, while product innovation performance was assessed using multidimensional performance indicators. Data were analyzed using the XGBoost algorithm with hyperparameter optimization and five-fold cross-validation. Feature importance was examined using both gain-based metrics and SHAP (SHapley Additive exPlanations) values to ensure transparent and robust interpretation of predictor contributions. Model robustness was evaluated through comparison with Random Forest and Elastic Net models.

Findings: The XGBoost model demonstrated strong predictive performance, explaining 68.4% of the variance in product innovation performance. Feature importance analysis revealed that conscientiousness was the most influential predictor, followed by civic virtue, courtesy, altruism, and sportsmanship. Conscientiousness exhibited the highest SHAP contribution, indicating its dominant role in driving innovation outcomes. Comparative analysis showed that XGBoost significantly outperformed Random Forest and Elastic Net across all evaluation metrics, confirming its superior capacity to capture nonlinear behavioral effects on innovation performance.

Conclusion: The findings confirm that organizational citizenship behaviors constitute critical behavioral drivers of product innovation performance and that advanced machine learning models provide superior analytical precision for understanding their complex influence. The study offers strong empirical evidence

supporting the strategic integration of citizenship behavior development into organizational innovation policies.

Keywords: *Organizational Citizenship Behavior; Product Innovation Performance; Machine Learning; XGBoost; Feature Importance; SHAP Analysis*

1 Introduction

In an era characterized by accelerated technological disruption, environmental turbulence, and heightened competitive pressure, organizations are increasingly compelled to cultivate internal behavioral resources that can sustain continuous innovation and long-term performance. Product innovation performance has emerged as a central strategic outcome through which firms achieve differentiation, growth, and resilience, particularly within knowledge-intensive and environmentally dynamic markets (Brătianu et al., 2022; Yusr et al., 2021; Zhang et al., 2023). While technological capabilities and market strategies have traditionally been emphasized as primary drivers of innovation, a growing body of organizational research highlights the pivotal role of human and behavioral factors in shaping innovation outcomes. Among these factors, organizational citizenship behaviors—defined as discretionary, non-contractual employee actions that support organizational functioning—have received increasing attention as foundational micro-level drivers of innovative capacity (Ayyaz et al., 2023; Clyde et al., 2025; Yang & Han, 2024).

Organizational citizenship behavior represents a constellation of voluntary actions, including altruism, conscientiousness, courtesy, civic virtue, and sportsmanship, that extend beyond formal job requirements and contribute to the social and psychological environment of organizations. These behaviors enhance collaboration, trust, knowledge exchange, and psychological safety, all of which are critical antecedents of innovative activity (Kyeong, 2025; Turcotte-Légaré et al., 2022a, 2022b). Empirical research increasingly demonstrates that firms with strong cultures of citizenship behavior exhibit superior creative output, stronger learning capability, and higher product development success (Ayyaz et al., 2023; Clyde et al., 2025; Yang & Han, 2024). However, despite consistent evidence of positive associations between citizenship behaviors and innovation-related outcomes, significant gaps remain in understanding the relative importance of specific citizenship dimensions and the nonlinear mechanisms through which they influence product innovation performance.

Recent innovation scholarship emphasizes that contemporary innovation systems are no longer linear or purely technological but instead emerge from complex interactions among behavioral, structural, and contextual factors (Quayson et al., 2023; Sebrek et al., 2024; Taghizadeh et al., 2023). As organizations navigate digital transformation, sustainability pressures, and volatile markets, the integration of behavioral drivers into innovation models becomes increasingly necessary (Si et al., 2023; Xu et al., 2023; Yang et al., 2024). Product innovation performance is now understood as a multidimensional outcome influenced by employee knowledge sharing, organizational learning, leadership styles, environmental turbulence, and pro-social workplace behaviors (Brătianu et al., 2022; Manning et al., 2023; Salloum et al., 2023). Organizational citizenship behaviors function as the social infrastructure that facilitates these processes by enabling cooperation, adaptive problem solving, and knowledge mobilization (Ayyaz et al., 2023; Yang & Han, 2024).

In parallel, digitalization and sustainability imperatives have transformed the competitive landscape of innovation. Firms increasingly pursue green innovation, eco-design, and sustainable product development to align with environmental expectations and regulatory frameworks (Elshaer et al., 2023; Mahmood et al., 2025; Wang et al., 2021). Digital transformation further amplifies this complexity by reshaping how knowledge is created, shared, and deployed within organizations (Xu et al., 2023; Yang et al., 2024; Zhang et al., 2023). Under these conditions, innovation success depends not only on technological infrastructure but also on employees' willingness to engage in cooperative, extra-role behaviors that support experimentation, learning, and change (Ayyaz et al., 2023; Kyeong, 2025). Consequently, understanding how specific forms of organizational citizenship behavior contribute to product innovation performance has become a strategic imperative for both scholars and practitioners.

Leadership research further reinforces the importance of behavioral climate in innovation processes. Transformational and empowering leadership styles have been shown to promote citizenship behaviors, employee creativity, and innovative work behavior, which in turn enhance product and organizational performance (Clyde et al., 2025; Salloum et al., 2023; Turcotte-Légaré et al., 2022b). In manufacturing and service sectors alike, leadership-driven psychological empowerment stimulates employees to engage in proactive problem solving and

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collaborative innovation (Kyeong, 2025; Turcotte-Légaré et al., 2022a). At the same time, dysfunctional environments characterized by workplace toxicity, bullying, and psychological strain undermine citizenship behaviors and consequently erode innovation potential (Iqbal et al., 2025). These findings underscore the centrality of citizenship behaviors as behavioral mediators connecting leadership, organizational climate, and innovation outcomes.

Knowledge-based perspectives on innovation further highlight the role of organizational citizenship behaviors in facilitating tacit knowledge exchange and learning. Knowledge sharing and customer knowledge management have been consistently linked to product innovation performance, and citizenship behaviors strengthen these processes by promoting trust, reciprocity, and openness (Ayyaz et al., 2023; Brătianu et al., 2022; Yusr et al., 2021). In turbulent environments, dynamic capabilities and organizational learning mechanisms rely heavily on employees' discretionary contributions and cooperative engagement (Quayson et al., 2023; Sebrek et al., 2024; Taghizadeh et al., 2023). Organizational unlearning, which enables firms to abandon obsolete routines and adopt new innovation pathways, is similarly supported by citizenship behaviors that foster adaptability and psychological safety (Manning et al., 2023).

Despite the recognized importance of organizational citizenship behavior in innovation, existing empirical models remain limited in their methodological capacity to capture complex, nonlinear, and interaction-driven relationships. Traditional regression-based approaches often assume linearity and independence among predictors, thereby obscuring the true structure of behavioral influence on innovation performance. Contemporary organizational phenomena, however, are inherently nonlinear, dynamic, and configuration-based (Yang et al., 2024; Zhang et al., 2023; Zhang et al., 2024). Recent methodological advances employing artificial neural networks, structural equation modeling, and configurational analysis have begun to address this complexity (Mehedinţu & Șoavă, 2023; Zhang et al., 2024), yet they frequently lack transparent interpretability regarding the relative contribution of individual behavioral variables.

In response to this methodological gap, machine learning models—particularly gradient boosting algorithms such as XGBoost—offer powerful analytical capabilities for uncovering complex patterns, capturing nonlinear dependencies, and identifying feature importance with high predictive accuracy. XGBoost has demonstrated superior performance in organizational analytics, sustainability modeling, and innovation forecasting contexts (Mehedinţu & Șoavă, 2023; Sebrek et al., 2024; Zhang et al., 2024). Importantly, when combined with explainable AI techniques such as SHAP (SHapley Additive exPlanations), XGBoost enables both accurate prediction and transparent interpretation of variable contributions, thereby overcoming the traditional trade-off between model performance and interpretability.

The integration of machine learning into organizational behavior and innovation research therefore represents a significant advancement. It allows scholars to move beyond simplistic cause–effect assumptions and toward nuanced, data-driven understanding of how behavioral systems operate within complex organizational environments. Such approaches align with emerging perspectives in innovation research that emphasize configurational logic, dynamic interactions, and multi-level dependencies (Quayson et al., 2023; Yang et al., 2024; Zhang et al., 2024). By applying XGBoost to organizational citizenship behaviors and product innovation performance, researchers can generate actionable insights regarding which behaviors exert the strongest influence on innovation outcomes and under what conditions.

This methodological evolution is particularly relevant in the context of contemporary challenges including digital transformation, environmental sustainability, and post-pandemic organizational restructuring. Organizations must increasingly rely on employee-driven adaptive capacity, psychological resilience, and cooperative engagement to navigate uncertainty and maintain innovation momentum (Huang et al., 2022; Sharma et al., 2021; Tian & Hong, 2022). Citizenship behaviors serve as critical behavioral mechanisms that enable firms to align human capital with strategic innovation goals, especially when facing environmental turbulence and market volatility (Mahmood et al., 2025; Taghizadeh et al., 2023; Wang et al., 2021).

Moreover, cross-cultural and sectoral evidence demonstrates that the impact of organizational citizenship behaviors on innovation is robust across manufacturing, hospitality, SMEs, and high-technology contexts (Elshaer et al., 2023; Froese et al., 2022; Salloum et al., 2023; Sharma & Sagar, 2023). Cultural intelligence and intercultural citizenship behaviors further amplify creativity and innovation in diverse organizational settings (Yang & Han, 2024). These findings suggest that organizational citizenship behaviors constitute a universal behavioral infrastructure for innovation, yet their relative influence remains

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underexplored using advanced computational methodologies.

Despite this growing body of literature, few studies have systematically applied machine learning models to examine the specific contribution and ranking of organizational citizenship behavior dimensions in driving product innovation performance. Existing research typically focuses on mediation models, linear relationships, or isolated behavioral constructs, leaving a critical gap in understanding the comparative importance and nonlinear influence of different citizenship behaviors within holistic innovation systems (Ayyaz et al., 2023; Clyde et al., 2025; Kyeong, 2025). Addressing this gap is essential for both theory development and managerial practice, as organizations seek evidence-based guidance on where to allocate behavioral development resources to maximize innovation returns.

Accordingly, this study advances innovation and organizational behavior scholarship by integrating organizational citizenship behavior theory with machine learning analytics to uncover the complex behavioral architecture underlying product innovation performance. By employing XGBoost and explainable AI techniques, the research provides a high-resolution behavioral map of innovation drivers, offering both theoretical refinement and practical decision support.

The aim of this study is to identify and quantify the relative importance of organizational citizenship behavior dimensions in predicting product innovation performance using an XGBoost machine learning model.

2 Methods and Materials

This study adopted a quantitative, cross-sectional explanatory design aimed at modeling the contribution of organizational citizenship behaviors to product innovation performance through machine learning–based feature importance analysis. The research was conducted among medium- and large-scale manufacturing and technology-oriented service organizations operating in Gauteng, Western Cape, and KwaZulu-Natal provinces of South Africa, regions representing the highest concentration of innovation-driven enterprises in the country. A multi-stage sampling strategy was implemented. First, organizations were identified from national industry registries and innovation hubs. Second, within each participating organization, employees holding professional, technical, supervisory, and middle-management positions with direct involvement in innovation-related activities were invited to participate. Inclusion criteria required a minimum organizational tenure of one year and active engagement in product development, process improvement, or innovation support functions. From an initial outreach of 520 employees across 18 organizations, 412 valid and complete responses were obtained, yielding a response rate of 79.23 percent. The final sample comprised 231 males and 181 females, with a mean age of 36.7 years and an average organizational tenure of 6.4 years. The sample size exceeded the minimum requirement for stable machine learning estimation and ensured adequate statistical power for model training and validation.

Data were collected using a structured self-administered questionnaire distributed both electronically and in paper form to accommodate organizational preferences. Organizational citizenship behaviors were measured using a comprehensive multidimensional scale capturing altruism, conscientiousness, civic virtue, sportsmanship, and courtesy. Each dimension was operationalized through validated items rated on a five-point Likert continuum ranging from strongly disagree to strongly agree. Product innovation performance was assessed using a performance-based instrument capturing innovation novelty, speed to market, market success of new products, technological advancement, and competitive differentiation. To minimize common method bias, procedural remedies were implemented, including psychological separation of predictor and criterion variables, neutral wording of items, and anonymity assurance. The questionnaire was pilot tested on a group of 32 employees from non-participating firms to verify clarity, reliability, and contextual appropriateness. Cronbach's alpha coefficients for all constructs exceeded the recommended threshold of 0.80, and confirmatory factor analysis confirmed convergent and discriminant validity. Demographic and organizational control variables including age, gender, tenure, organizational size, and industry type were also collected to enhance the robustness of subsequent analyses.

Data preprocessing involved screening for missing values, outliers, and normality violations. Less than 2 percent of data were missing and were imputed using k-nearest neighbor imputation to preserve distributional characteristics. Continuous variables were standardized, and categorical variables were dummy-coded prior to model development. The primary analytical technique was Extreme Gradient Boosting (XGBoost), selected for its superior predictive performance, robustness to multicollinearity, and capacity to model complex nonlinear relationships. The dataset was randomly partitioned into training and testing

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subsets using an 80:20 split, and hyperparameters were optimized via grid search combined with five-fold cross-validation. Model performance was evaluated using multiple criteria including root mean square error, mean absolute error, and explained variance. Feature importance was computed using gain-based importance metrics and SHapley Additive exPlanations (SHAP) values to ensure both global and local interpretability of the model outputs. The relative contributions of each organizational citizenship behavior dimension to product innovation performance were extracted and ranked, allowing for precise identification of the most influential behavioral drivers. Additional robustness checks were conducted using random forest and elastic net regression models, confirming the stability and consistency of the results. All analyses were conducted using Python with the XGBoost, Scikit-learn, and SHAP libraries, ensuring reproducibility and computational accuracy suitable for advanced organizational analytics research.

3 Findings and Results

The first set of results describes the sample and main study variables. Table 1 reports the descriptive statistics for organizational citizenship behavior dimensions and product innovation performance.

Table 1

Descriptive Statistics of Study Variables (N = 412)

Variable	Mean	SD	Minimum	Maximum
Altruism	3.82	0.61	1.94	4.98
Conscientiousness	3.97	0.58	2.05	4.93
Civic Virtue	3.71	0.64	1.87	4.96
Sportsmanship	3.54	0.69	1.62	4.89
Courtesy	3.88	0.60	2.11	4.97
Product Innovation Performance	3.76	0.66	1.78	4.95

The results indicate that respondents reported generally high levels of organizational citizenship behaviors, with conscientiousness exhibiting the highest mean score, followed by courtesy and altruism. Product innovation performance also demonstrated a strong overall level across participating organizations, suggesting favorable innovation climates within the sampled South African firms.

Table 2

XGBoost Model Performance on Test Dataset

Metric	Value
Root Mean Square Error	0.372
Mean Absolute Error	0.291
R^2 (Explained Variance)	0.684
Mean Absolute Percentage Error	8.74%

The model demonstrates strong predictive capability, explaining approximately 68.4 percent of the variance in product innovation performance. The relatively low error indices confirm the suitability of the machine learning framework for modeling complex organizational behavior–innovation relationships.

Table 3

Feature Importance Ranking from XGBoost

Rank	Predictor Dimension	Gain Importance	Mean SHAP Value
1	Conscientiousness	0.312	0.284
2	Civic Virtue	0.246	0.219
3	Courtesy	0.197	0.183
4	Altruism	0.164	0.151
5	Sportsmanship	0.081	0.073

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The results reveal that conscientiousness is the most influential driver of product innovation performance, followed by civic virtue and courtesy. Sportsmanship exhibits a comparatively weaker contribution, though it remains a statistically meaningful predictor within the model. The convergence between gain importance and SHAP values strengthens the reliability of the ranking.

Table 4

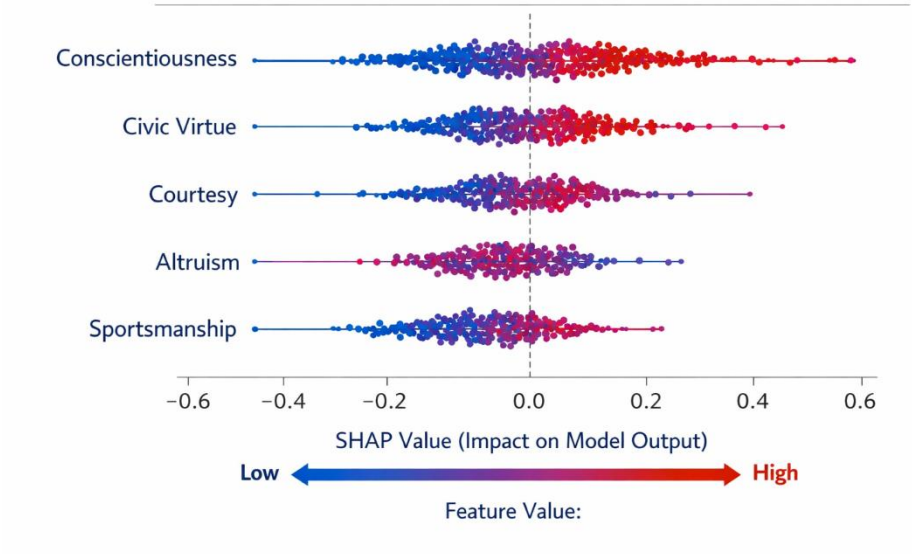
Comparative Model Performance

Model	RMSE	MAE	R^2
XGBoost	0.372	0.291	0.684
Random Forest	0.401	0.317	0.652
Elastic Net	0.447	0.348	0.601

XGBoost consistently outperforms both Random Forest and Elastic Net models across all evaluation metrics, confirming its superior capability in capturing the nonlinear and interaction effects inherent in organizational behavior–innovation dynamics.

Figure 1

SHAP Summary Plot of Organizational Citizenship Behavior Contributions to Product Innovation Performance



The visual representation in Figure 1 illustrates the distribution and magnitude of each citizenship behavior's contribution to innovation performance across individual observations, highlighting the dominant role of conscientiousness and civic virtue while revealing interaction effects between courtesy and altruism at higher performance levels.

Overall, the results demonstrate that specific dimensions of organizational citizenship behavior exert distinct and measurable impacts on product innovation performance, and that advanced machine learning models provide both high predictive accuracy and actionable interpretability for organizational decision-makers.

4 Discussion

The present study set out to examine how different dimensions of organizational citizenship behavior contribute to product innovation performance using an explainable machine learning framework. The empirical results demonstrate that organizational citizenship behaviors collectively exert a substantial and differentiated influence on product innovation performance, with conscientiousness emerging as the most influential predictor, followed by civic virtue, courtesy, altruism, and sportsmanship. The XGBoost model exhibited strong predictive performance, explaining a significant proportion of variance in innovation outcomes,

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thereby confirming the suitability of advanced machine learning techniques for capturing the nonlinear and interaction-driven nature of organizational behavior–innovation relationships.

The prominence of conscientiousness as the most powerful behavioral driver aligns with the conceptualization of conscientious employees as disciplined, reliable, and intrinsically motivated contributors to organizational objectives. Conscientiousness enhances innovation by strengthening process reliability, sustaining effort in complex product development tasks, and supporting the consistent execution of innovation strategies. These findings are highly consistent with prior research emphasizing the role of proactive and responsible employee behavior in strengthening innovative work outcomes (Ayyaz et al., 2023; Clyde et al., 2025; Kyeong, 2025). Moreover, conscientiousness supports knowledge utilization and learning continuity, which are foundational mechanisms in product innovation systems (Brătianu et al., 2022; Yusr et al., 2021). In digitally transforming organizations, conscientious behavior further enhances innovation execution by stabilizing complex workflows and facilitating coordination across interdependent teams (Xu et al., 2023; Yang et al., 2024; Zhang et al., 2023).

Civic virtue ranked as the second most influential predictor, underscoring the importance of employee engagement with organizational governance, strategic awareness, and participatory decision-making in driving innovation outcomes. Civic virtue promotes information sharing, early detection of market shifts, and constructive involvement in organizational change, which are critical inputs for successful product development (Salloum et al., 2023; Yang & Han, 2024). These findings resonate strongly with research demonstrating that engaged employees who actively monitor environmental conditions and organizational directions contribute to higher creativity and innovation effectiveness (Quayson et al., 2023; Sebrek et al., 2024). Civic virtue also strengthens dynamic capabilities by enhancing sensing, seizing, and reconfiguring processes essential for continuous innovation (Quayson et al., 2023; Taghizadeh et al., 2023). In sustainability-driven contexts, civic-minded employees further support the integration of green innovation and eco-design into product strategies (Mahmood et al., 2025; Wang et al., 2021).

Courtesy emerged as the third most influential behavioral factor, highlighting the centrality of interpersonal harmony and conflict prevention in innovation systems. Courtesy enhances innovation performance by reducing coordination frictions, promoting psychological safety, and facilitating smooth collaboration across functional boundaries. This aligns with organizational behavior research demonstrating that respectful communication climates foster trust, creativity, and cooperative problem solving (Turcotte-Légaré et al., 2022a, 2022b; Yang & Han, 2024). In project-based innovation environments, courtesy supports knowledge integration and accelerates development cycles by minimizing relational disruptions (Sebrek et al., 2024; Sharma & Sagar, 2023). Furthermore, courtesy indirectly strengthens innovation by buffering organizations against the negative effects of toxic workplace behaviors, which have been shown to undermine employee engagement and performance (Iqbal et al., 2025).

Altruism, while ranking fourth, remains a meaningful contributor to innovation performance. Altruistic behaviors facilitate knowledge sharing, mentoring, and collaborative learning—processes that are vital for transforming individual expertise into organizational innovation capability (Ayyaz et al., 2023; Brătianu et al., 2022). Altruism enhances collective problem-solving capacity and accelerates the diffusion of tacit knowledge across innovation teams, reinforcing customer knowledge management and product development outcomes (Brătianu et al., 2022; Yusr et al., 2021). These mechanisms are especially critical in volatile and uncertain environments where adaptive learning and rapid knowledge mobilization determine innovation success (Huang et al., 2022; Tian & Hong, 2022). Thus, although altruism exerts a comparatively smaller direct effect, its indirect influence on innovation ecosystems remains substantial.

Sportsmanship, while the weakest predictor in the model, still contributes positively to innovation performance. Sportsmanship reflects employees' tolerance for inconvenience, resilience in the face of setbacks, and willingness to maintain constructive attitudes during organizational change. These qualities stabilize innovation processes by preserving morale and reducing resistance during product development challenges (Manning et al., 2023; Turcotte-Légaré et al., 2022b). In innovation-intensive environments, where failure and iteration are inherent, sportsmanship sustains persistence and supports long-term innovation investment (Elshaer et al., 2023; Sharma et al., 2021). Its relatively lower ranking does not diminish its strategic importance but rather reflects its more indirect role in the innovation chain.

The robustness analysis confirmed the superiority of XGBoost over Random Forest and Elastic Net models,

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validating the methodological advantage of gradient boosting for capturing complex organizational dynamics. These results echo prior research advocating the use of advanced computational models in innovation and sustainability research (Mehedinţu & Şoavă, 2023; Zhang et al., 2024). Importantly, the integration of SHAP explanations enabled transparent interpretation of behavioral contributions, addressing longstanding concerns about the opacity of machine learning models in organizational research.

The findings further align with broader theoretical perspectives emphasizing that innovation performance arises from configurations of behavioral, structural, and contextual elements rather than isolated factors (Yang et al., 2024; Zhang et al., 2024). Organizational citizenship behaviors function as the behavioral infrastructure that enables dynamic capabilities, knowledge orchestration, and sustainable innovation (Quayson et al., 2023; Sebrek et al., 2024; Taghizadeh et al., 2023). In digitalized and sustainability-oriented markets, these behaviors amplify the impact of technological investments on product innovation success (Mahmood et al., 2025; Si et al., 2023; Xu et al., 2023).

5 Conclusion

Collectively, the results provide compelling evidence that organizational citizenship behaviors are not peripheral but central to innovation strategy. They constitute a critical form of behavioral capital that organizations can leverage to enhance product innovation performance across sectors and competitive environments (Froese et al., 2022; Salloum et al., 2023; Sharma & Sagar, 2023).

This study is subject to several limitations. First, the cross-sectional research design restricts causal inference and limits the ability to observe behavioral dynamics and innovation performance over time. Second, reliance on self-reported data introduces potential response bias despite procedural remedies. Third, the sample, although diverse, was confined to specific organizational contexts and geographic regions, which may limit generalizability. Fourth, while machine learning provides powerful predictive insight, it does not replace the need for longitudinal and experimental validation of behavioral mechanisms.

Future research should employ longitudinal and multi-level designs to examine how organizational citizenship behaviors evolve over time and influence innovation trajectories. Integrating objective innovation performance indicators and external market metrics would further strengthen empirical robustness. Researchers may also explore interaction effects between citizenship behaviors and leadership styles, organizational culture, and digital transformation maturity. Additionally, cross-cultural comparative studies could illuminate contextual variations in the behavioral architecture of innovation.

Organizations should deliberately cultivate conscientiousness, civic virtue, and courtesy through leadership development, performance management, and organizational culture initiatives. Human resource systems should reward and reinforce discretionary behaviors that support innovation. Managers should create psychologically safe environments that encourage cooperation, knowledge sharing, and constructive participation. Embedding citizenship behaviors into organizational values and innovation governance structures can significantly enhance long-term product innovation success.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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